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Regional-scale groundwater geoscience in southern Ontario: an Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists open house

H.A.J. Russell, D. Ford, E.H. Priebe, and S. Holysh
(compilers)

2018

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Canada

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2018

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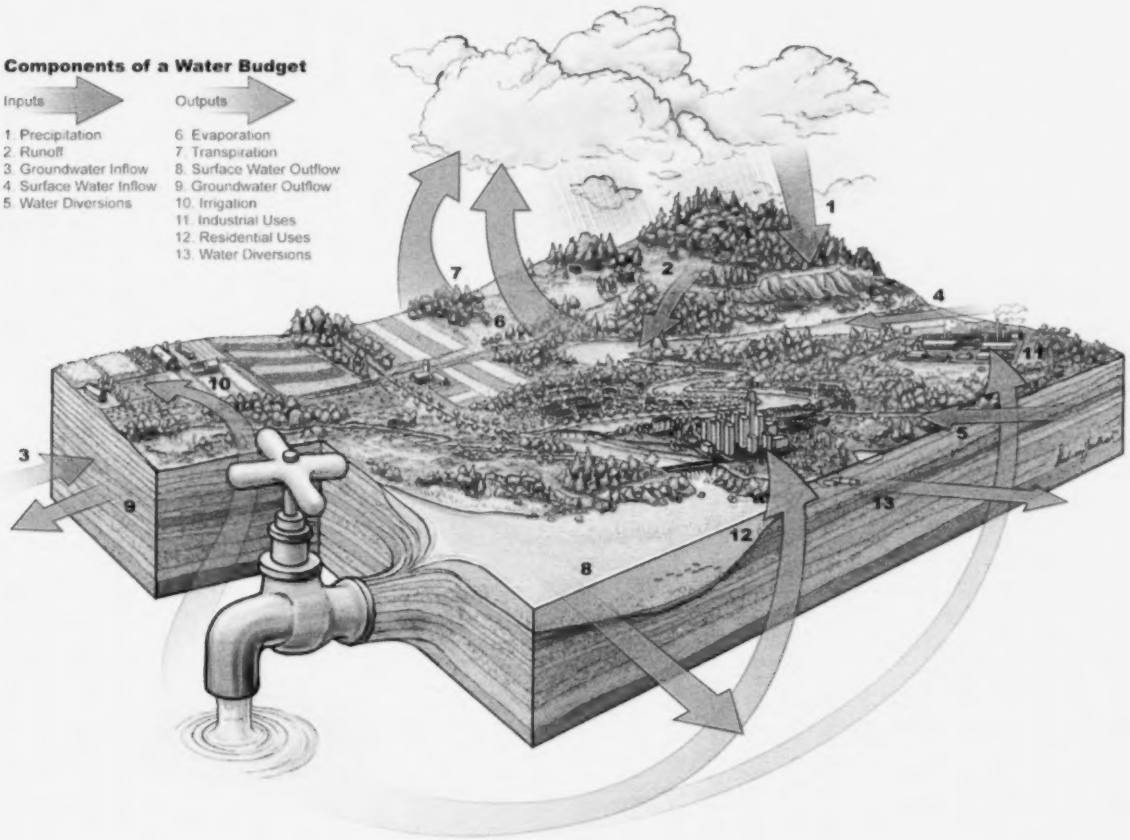
Regional-scale groundwater geoscience in southern Ontario: an Ontario Geological Survey, Geological Survey of Canada, and Conservation Ontario Geoscientists open house

February 28th and March 1st, 2018 | Delta Hotel, Guelph



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Steve Holysh Oak Ridges Moraine

Geological Survey of Canada, Open File 8363.

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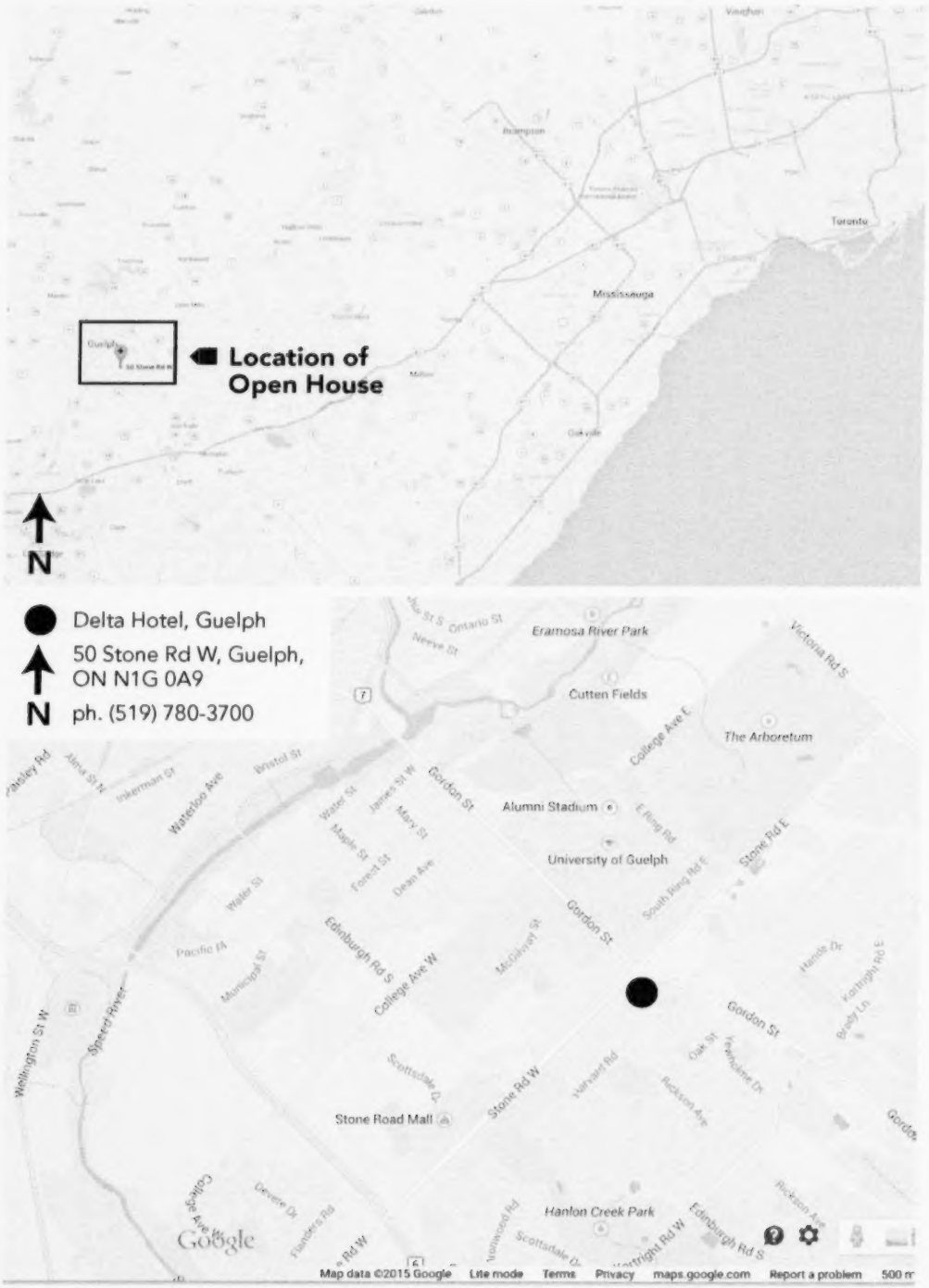
Location Map



Program

February 28. Oral Presentations

START	END	DURATION	TITLE	PRESENTER	AFFILIATION
8:00	9:00		Registration and Networking		
9:00	9:10	0:10	Introduction	Simard and Bolduc	OGS/GSC
9:10	9:30	0:20	The Ontario Geological Survey's Groundwater Initiative: Deliverables, Data, Derivatives and Future Direction	Riley Mulligan	OGS
9:30	9:50	0:20	Highlights of OGS – GSC Collaboration on Regional Groundwater Studies: 2017 – 2018	Hazen Russell	GSC
9:50	10:10	0:20	The Science Behind Ontario's Water Quantity Management Review	Heather Brodie-Brown	MOECC
10:10	10:40	0:30	Break		
10:40	11:00	0:20	Linked Data: Connecting Data Using Google Discoverability	Boyan Brodaric	GSC
11:00	11:20	0:20	Public Access to U.S. Geological Survey Publications and Digital Data	Sandra Eberts	USGS
11:20	11:40	0:20	Update on Groundwater Activities under the Canada Ontario Agreement and Great Lakes Water Quality Agreement	Scott MacRitchie	MOECC
11:40	12:00	0:20	The Microvibe, a Broad band, Light-Weight and Cost Effective Seismic Source for Near Surface Imaging	André Pugin	GSC
12:00	13:00	1:00	Lunch		
13:00	13:20	0:20	The Use of Wide Spectrum Groundwater Geochemistry in Regional Groundwater Mapping in Ontario	Stew Hamilton	OGS
13:20	13:40	0:20	Chemical and Isotopic Evidence of Fragmented Recharge Areas for the Carbonate Aquifers of the Niagara Escarpment	Elizabeth Priebe	OGS
13:40	14:00	0:20	Assessing the Integrity of Aquitards: the Newmarket Till at Ajax	Ramina Rashtchi	University of Ottawa
14:00	14:20	0:20	Newmarket Till Aquitard: Optimum Grain Packing with a Pore-Filling Calcite-Rich Cement	Bruce Kjarsgaard	GSC
14:20	14:40	0:20	Break		
14:40	15:00	0:20	Quaternary Geology and Hydrostratigraphy of the Central Simcoe County Area, Southern Ontario	Riley Mulligan	OGS
15:00	15:20	0:20	Challenges in Building a 3-D Geologic Model of the Paleozoic Bedrock of Southern Ontario	Terry Carter	Independent
15:20	15:40	0:20	A Fully Integrated Groundwater – Surface-Water Modelling Platform for Southern Ontario	Steven Frey	Aquanty
15:40	16:00	0:20	Data Capture, Consolidation and Reclassification: Moving Toward a Geological Framework to Support Groundwater Management	Hazen Russell	GSC
16:00	16:20	0:20	Wrap-Up		

March 1. Oral Presentations

START	END	DURATION	TITLE	PRESENTER	AFFILIATION
8:30	9:00		Registration and Networking		
9:00	9:10	0:10	Welcome to Day 2 Conservation Authorities Geoscience	Ford and Holysh	CRTCA / Oak Ridges Water
9:10	9:20	0:10	Introduction to Model Management Session	Steve Holysh	Oak Ridges Water
9:20	9:40	0:20	Re-Purposing Models – Experiences and Opportunities	Mason Marchildon	Oak Ridges Water
9:40	10:00	0:20	Moving Forward: Water Management Insights from the Development and Application of Fully Integrated Tier 3 Models	Dirk Kassenaar	Earthfx
10:00	10:20	0:20	Assessing Development Alternatives Utilizing Tier 3 Models: Balancing Runoff and Ecological Function	Paul Martin	Matrix Solutions
10:20	10:40	0:20	Waterloo's Regional Model – A Multi-Purpose Water Management Tool	Eric Hodgins	Waterloo
10:40	11:00	0:20	Break		
11:00	12:00	1:00	Panel Discussion		
12:00	13:00	1:00	Lunch		
13:00	13:20	0:20	Use of Provincial Data by Conservation Authorities	Ryan Post and Jayme Campbell	NPCA,NVCA
13:20	13:40	0:20	Co-existence of industrial organic contaminant plumes with municipal water supply wells in fractured rock aquifers	Beth Parker	G360, University of Guelph
13:40	14:00	0:20	Use of Regional Hydrogeologic Knowledge for Designing Geothermal Energy Source for Low-Carbon Residential Community	Warren Lusk	MOECC
14:00	14:20	0:20	Optimum Use of Source Water Protection Modelling Results	Fred Carpio	CLOCA
14:20	14:40	0:20	Groundwater Resources Management in the Grand River Watershed: Community Engagement and Making the Most of Our Water Budget Tools	Sonja Strynatka	GRCA
14:40	15:00	0:20	Break		
15:00	15:20	0:20	Enhancing Flood and Drought Forecasting Tools in the South Nation River Watershed	Michael Melaney and Steven Frey	South Nation CA and Aquanty
15:20	15:40	0:20	Investigation of the Potsdam Group Sandstone Aquifer Vulnerability with the DFN-M Approach	Peeter Pehme	G360, University of Guelph
15:40	16:00	0:20	An Integrated Investigation of Groundwater – Surface-Water Interactions Under Conditions of Changing Climate in the Great Lakes Basin	Elisha Persaud	University of Guelph
16:00	16:10	0:10	Wrap-Up	Russell / Priebe / Ford / Holysh	

February 28 and March 1. Poster Presentations

	TITLE	AUTHOR	AFFILIATION
1	Bottoms Up: Developing a New Bedrock Surface for the Niagara Peninsula	Abigail Burt	OGS
2	3-Dimensional Mapping of Quaternary Deposits in the Southern Part of the County of Simcoe, Southern Ontario	Andy Bajc	OGS
3	Quaternary Geology and Hydrostratigraphy of the Central Simcoe County Area, Southern Ontario	Riley Mulligan	OGS
4	Chemical and Isotopic Evidence of Fragmented Recharge Areas for the Carbonate Aquifers of the Niagara Escarpment	Elizabeth Priebe	OGS
5	The Use of Wide Spectrum Groundwater Geochemistry in Regional Groundwater Mapping in Ontario	Stew Hamilton	OGS
6	The Ambient Groundwater Geochemistry Program: Pilot Project in Northern Ontario Precambrian Aquifers	Kayla Dell	OGS
7	Characterization of Full 3D Hydraulic Conductivity Tensors of Hydrostratigraphic Units Applied to Innisfil Creek Watershed, Ontario	Nicolas Benoit	GSC
8	Using Oil, Gas and Salt Resources Library Well Data in Groundwater Research	Jordan Clark	OGSRL
9	The Bells Corner Borehole Geophysical Calibration Facility of the Geological Survey of Canada	Heather Crow	GSC
10	Pinning Down Demand for Groundwater Geoscience: From Narratives to Numbers	Shona de Jong	Queen's University
11	Near Surface Seismic Database: Future Online GSC Data Delivery	André Pugin	GSC
12	A Chemostratigraphic Framework for Southern Ontario: A Progress Report	Ross Knight	GSC
13	Downscaling SMOS/SMAP Soil Moisture Product Using Radarsat Constellation Mission (RCM) Data: A Case Study in Southern Ontario	Junhua Li	GSC
14	An Animation of the 3D Phanerozoic Geological Model of Southern Ontario	Hazen Russell	GSC
15	A Numerical Study of Barometric Loading	Robert Walsh	Geofirma Engineering Ltd.

Context

Following the successful 2017 Ontario Geological Survey (OGS) – Geological Survey of Canada (GSC) Open House and the addition of a second day for Conservation Authorities, the same format has been adopted this year.

The first day of the open house continues to profile OGS and GSC research with an attempt to integrate perspectives from the USGS and other provincial ministries. Additionally this year two talks highlight groundwater work at the Ministry of Environment and Climate Change (MOECC). Day two focuses on work completed by, and in collaboration with Conservation Authorities in southern and eastern Ontario. Talks on the two days are 20 minutes in length, and time has been allocated during health breaks and at the end of the day to network and also interact with authors who decided to have poster presentations. Poster presentations will be on display for the complete two days.

In 2016 four key issues were identified as being the focus of presentations. This year we continue to emphasize:

- Outcomes of the OGS-GSC 2012-2015 Groundwater Geoscience Knowledge Gap Analysis
- Canada – USA Great Lakes Water Quality Agreement /Canada – Ontario Great Lakes Agreement
- Provincial Groundwater Data Management and modelling.
- Conservation Authority Geoscience

As in previous years, the 2018 open house builds upon the issue of outreach and communications identified in the 2012-2015 OGS Gaps analyses[1]. It is the third in a series of annual open houses planned to connect groundwater practitioners with policy makers in southern Ontario, and share updates on OGS-GSC geoscience activities. Following each open house the organizers will complete an evaluation of the success of the open house and refine the format and content for the following year. The OGS and GSC are committed to developing this open house for a four-year period until March 2019 when the exercise will be re-evaluated.

Acknowledgements

Day two has been sponsored by a contribution to Conservation Ontario Geoscientists Group by the International Association of Hydrogeologists (IAH) Canadian Chapter. The time and effort of the workshop presenters and their respective agencies is much appreciated. Rhianydd Phillips, and Jean Francois Bureau helped with a variety of planning issues. The Conservation Authorities participation has been coordinated by Conservation Ontario's Geoscience Group (COGG). An internal review at the GSC by Marc Hinton is much appreciated. Donna Ferguson and Glenn Ferguson completed graphic production of the workshop program. This is a contribution of the Groundwater Geoscience Program of the Geological Survey of Canada, Natural Resources Canada. This work is a contribution of the GSC-OGS Southern Ontario project on groundwater 2014 – 2019.

[1] Russell, H.A.J., Priebe, E.H., and Parker, J.R., 2015. Workshop Summary and Gap Analysis Report: Unifying Groundwater Science in Southern Ontario. Ontario Geological Survey, Open File Report. 6310, 64 p.

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3-Dimensional Mapping of Quaternary Deposits in the Southern Part of the County of Simcoe, Southern Ontario

Bajc[1], Andy F.; Riley P.M. Mulligan[1], Desmond R.B. Rainsford[1], André J.-M. Pugin[2], Ross D. Knight[2], and Heather L. Crow[2]

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A 3-dimensional (3-D) mapping investigation of Quaternary deposits in the southern part of the County of Simcoe is one of several 3-D mapping projects currently being undertaken as part of the Ontario Geological Survey's groundwater initiative within the Greater Golden Horseshoe area of southern Ontario. Following completion of these projects, a significant proportion of the most densely populated and fastest growing region of the country will be modelled in 3-dimensions, laying the foundation for regional syntheses of subsurface geology.

The objective of this project is to develop an interactive 3-D model of Quaternary geology that can: 1) aid in studies involving groundwater extraction, protection and remediation; 2) assist with the development of policies surrounding land use and nutrient management; and 3) help to further understand the interaction between surface and ground waters. A better understanding of the geometry and inherent properties of the Quaternary sediments that overlie bedrock will assist with the development of revised source water protection plans and with the development of a geoscience-based management plan for the groundwater resource.

Geoscience data collection was initiated in 2010 and consisted of detailed Quaternary mapping and sedimentological studies of the shallow subsurface, continuous coring to bedrock at 25 locations and a variety of geophysical surveys including: ground gravity, airborne time-domain electromagnetics, downhole geophysical logging and seismic reflection. Supplementary grain size, carbonate, heavy mineral and geochemical analyses enabled an improved interpretation of the subsurface stratigraphy.

The information gained from this work resulted in a refined understanding of drift thickness and bedrock topography for the Laurentian trough area as well as the identification of 6 regionally significant chronostratigraphic units further subdivided into 15 layers. The main elements of the model, from youngest to oldest, include: 1) postglacial valley-fill deposits; 2) Oak Ridges Moraine (ORM) and equivalent deposits; 3) Newmarket Till; 4) Scarborough-Thorncliffe Formation equivalents; 5) non-glacial (Sangamon-Middle Wisconsin) deposits and 6) Illinoian and possibly older glacial deposits. Advancements in the understanding of the regional-scale architecture, contact relationships and depositional settings of these elements has allowed for an improved knowledge of the Quaternary history of the region. Notable observations include the identification of a widespread, non-glacial unit in the deep subsurface that likely spans the Sangamon to Middle Wisconsin time interval and the recognition of significant topographic relief of the Newmarket Till, extending from drumlinized uplands into broad valleys previously interpreted as tunnel valleys produced by the catastrophic release of subglacial meltwater. A protracted evolution for these valleys is currently being proposed. The character of groundwater flow within valley settings is more complex than observed in valleys underlying the ORM to the south. In Southern Simcoe County, the valleys are largely infilled with fine-grained units and upward hydraulic gradients commonly inhibit interaction of shallow with deep groundwater flow systems.

Characterization of Full 3D Hydraulic Conductivity Tensors of Hydrostratigraphic Units Applied to Innisfil Creek Watershed, Ontario

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Variations of hydraulic conductivities (K) in hydrostratigraphic systems may significantly affect the flow velocity field and mass dispersion. Field data used for assessment of K are generally representative at a local scale only and for one or a few hydrofacies forming a specific hydrostratigraphic unit (HSU). Regional groundwater flow systems encompass a multitude of HSUs, where a given HSU can have K-range variability spanning several orders of magnitude. Therefore, for regional systems, blocks with respective K-equivalent have to be defined as part of each HSU. A major challenge under such conditions is to determine the spatial distribution of the full 3D K-tensor blocks (Kb) considering the effect of local scale variability in K. In this study, an efficient method is developed for regional characterization of the HSUs with 3D Kb. The method was tested for the Innisfil Creek watershed. For each HSU, it consists of the following major steps: (i) assessment of K from measured data; generation of the probability density function of K; definition of the spatial covariance of K; and geostatistical simulation of K at local scale; (ii) upscaling of the local scale realizations of K into full 3D Kb; definition of the spatial covariance of 3DKb; and definition of spatial distribution of the 3DKb. The preliminary results include a K database built using 1694 grain size analyses, 32 HSU borehole samples and 1086 transmissivity measurements in public wells. The grain size samples were collected by Ontario Geological Survey (OGS) from 15 boreholes in the South Simcoe area. Between 28 and 301 samples/HSU were analysed covering all of the 14 HSUs observed in the study area. K from grain size analyses were in good agreement with K based on laboratory permeability test measurements of field core. The database was completed with K assessments from specific capacity analyses in public wells, which have a strong bias from the high permeability formations. To obtain the local scale variability of K, only the results from grain size analyses were used mainly due to their sufficient quantity to define the probability density function of each HSUs and their results reflecting the expected strong variability of hydrofacies within a given HSU. Local scale K fields were simulated with non-conditional turning band simulation. These results were then upscaled to the block regional scale. In that regards, we revisited the Zhou et al. (2010) methodology for non-local 3D hydraulic conductivity full tensor upscaling using flow simulator. Preliminary results suggest no correlation between upscaled blocks within the study area. The upscaling methodology is still in development, upscaling parameters and validation criteria need to be tested. The final outputs of this study will be an ensemble of hydrostratigraphic models with equivalent 3D K-tensor parameters, which will be used to assess the impact of K and HSU uncertainties on groundwater flow modeling. The proposed methodology is appropriate for characterizing the uncertainty of groundwater flow and transport. For example, it can be used for aquifer vulnerability assessment and the delineation of wellhead protection areas.

Linked Data: Connecting Data Using Google Discoverability

Brodaric, Boyan

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Understanding surface water and groundwater interactions is crucial to integrated resource management. Obtaining relevant data is a first step, but finding and retrieving the data is challenging because the data are often scattered amongst databases maintained by different groundwater and surface water agencies, such as in Ontario. The emergence of data networks and web portals addresses this challenge partially, insofar as users can then access the data in a uniform way. However, there remain significant challenges in data discoverability and connectivity: (1) web portals are often difficult to find and use, and (2) links between different databases are absent. The latter is a major impediment to integrated resource management, due to the relative unavailability of data about relations between surface water and groundwater entities. Linked Data overcomes these challenges by describing links between entities on the web, using Semantic Web techniques, enabling the relations to be found and retrieved with web browsers and search engines. This complements existing web portals through re-use of their data access mechanisms while providing value-added information in the form of links.

Presented will be recent results from a project prototyping Linked Data for the Canadian hydro community. Water wells, aquifers, and monitoring sites from the Groundwater Information Network (Natural Resources Canada) are linked to watersheds, catchments and major water bodies from the National Hydrographic Network (Natural Resources Canada), and to stream gauges from the National Hydrometric Network (Environment and Climate Change Canada). This enables users to find and retrieve targeted information about surface water and groundwater interactions in the region. Planned future work includes expanding nationally within Canada, as well as internationally to the US to capture cross-border interactions. These early results position Linked Data as the next frontier in providing data for integrated resource management, particularly in situations where data is distributed amongst many agencies, as is the case in Ontario.

The Science behind Ontario's Water Quantity Management Review

Brodie-Brown[1], Heather; Tiffany Svensson[2], and Ian Macdonald[2]

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Water is vital to the health and integrity of our ecosystems and communities. The anticipated impacts of climate change have intensified concerns related to water security in Ontario. Improving our water resource information and assessing our existing water quantity management tools is a key step in ensuring that Ontario will be able to protect and manage water resources now and in the future.

The Ministry will provide an overview of work to modernize it's water quantity management framework (policy, program and science) to ensure a robust and adaptive approach to water resources management into the future, and the water quantity scientific work being undertaken to improve our understanding of water resources knowledge on Ontario. Key aspects of the water quantity science work being undertaken will be introduced, including:

Immediate

- development of a science & technical backgrounder
- a review of science/jurisdictional best practices
- assessment of Ontario's water (quantity) resources and management approaches in specific geographical areas
- water quantity data enhancements and development of an internal data website / platform
- water Quantity Protection External Working Group

Longer Term

- outfacing water quantity website (data platform and tools)
- enhance source protection water budgets and models
- new and enhanced science tools and approaches
- province-wide and/or additional local scale water quantity assessment
- enhanced monitoring

BluMetric will provide an overview of the water quantity assessment and management review work being undertaken in specific geographical areas in the province. Water Quantity Study Areas and Water Bottling Study areas being investigated as part of this work (Fig. 1).

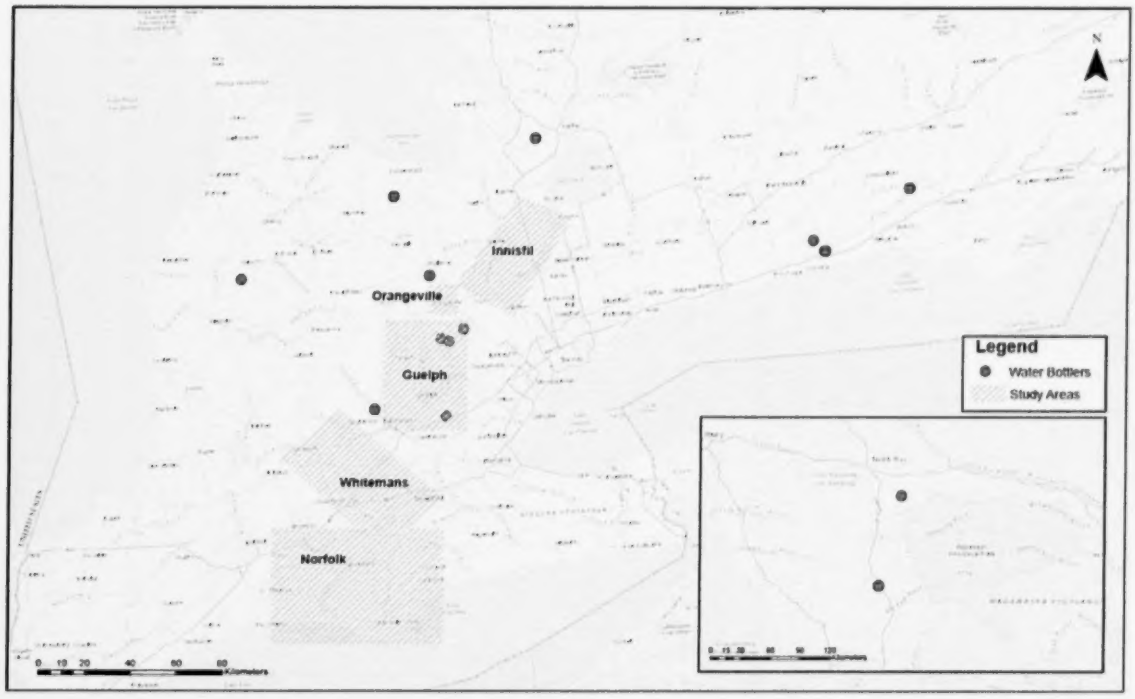

Figure 1. Map of southern Ontario with water quantity study areas and water bottler study areas illustrated.

Bottoms Up: Developing a New Bedrock Surface for the Niagara Peninsula

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The Niagara Peninsula three-dimensional (3-D) sediment mapping project was initiated in 2013 with the primary goal of constructing a model of regional-scale Quaternary deposits that form both regional and local aquifers and aquitards between Port Dover in the southwest, the Regional Municipality of Waterloo in the northwest and the Niagara River in the east. To date, the primary focus of the project has been on data acquisition.

Five shallow, high-resolution seismic reflection lines, ranging from 4.5 to 21.5 km in length, were acquired by the Geological Survey of Canada's (GSC) Near Surface Geophysics Section to determine whether multiple thalwegs exist within the buried Erigan channel, to delineate the lateral extent and geometry of gravel beds observed during drilling and to provide insight into late-glacial moraine systems. Downhole geophysical logging was conducted in monitoring wells to investigate chemical and physical properties of the sediments, and to verify the conversion of seismic reflection time sections to depths..

A 6828 station ground gravity survey was conducted along selected roads and highways at a nominal spacing of 100 m. The calculated gravity residuals were used to identify buried-bedrock valleys and guide subsequent drilling. The survey was effective in identifying deeply incised valleys, such as St. Davids and the northern end of the Erigan, but less definitive where valleys broaden and the deep regional and shallow residual components of the gravity are not as easily separated.

A total of 99 continuously cored boreholes with a combined length of 3192 m, 29 of which have been converted into monitoring wells, have been drilled for this project. The borehole data is augmented by 130 exposures, soil probe and hand-auger cores and extensive legacy datasets (water well records, oil and gas records, geotechnical records, published geological reports and archived field notes).

A key first step in the 3-D modelling process is to generate a high-quality bedrock topographic surface that forms the foundation layer for the overlying sediment model. The surface is interpolated using Datamine Studio® software after manually digitizing 3-D points identifying the top of rock onto the new and legacy borehole traces. Additional points were digitized adjacent to, or below, the borehole traces in order to refine the geometry of the surface and reduce potential effects of clustered data points. By modelling the gravity results using representative density values for the Quaternary and bedrock layers, and integrating with interpretations from seismic studies in the area, it is possible to further constrain the shape of the bedrock surface.

The resulting surface shows southward-dipping bedrock separated by the prominent features of the Niagara and Onondaga escarpments. Deep and narrow re-entrant valleys bisect the resistant escarpments, becoming wider where they cross softer formations.

Challenges in Building a 3-D Geologic Model of the Paleozoic Bedrock of Southern Ontario

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A regional 3-D geological model of the Paleozoic bedrock of southern Ontario is in its third year of development[2]. The current version is in the early stages of review and is scheduled to be available as a public domain product in autumn 2018. The model encompasses all south-western and south-central Ontario, an area of 110,000 km^2 and the complete Paleozoic sedimentary bedrock succession. This project is a collaboration of the Geological Survey of Canada, Ontario Geological Survey (OGS), Ontario Ministry of Natural Resources and Forestry (MNRF) and the Oil, Gas and Salt Resources Library (Library).

The model is constructed in Leapfrog® Hydro (Aranz Geo Limited) – an implicit modelling application. Layers representing 58 geological formations were constructed using formation depth data from 26,700 petroleum borehole records in the Ontario Petroleum Data System (OPDS), supplemented by hundreds of deep bedrock boreholes compiled by OGS. OPDS is an Oracle relational database built and maintained by the MNRF and the Library, representing borehole data collected over 150 years of petroleum drilling. Formation depth data in the borehole records comprise the primary data input for the 3-D model. Leapfrog also allows layers to be augmented by 3-D vector objects. For this model an OGS digital bedrock topography surface is combined with a revised 2-D subcrop geology map to assemble a grid of 3-D points that approximate the subcrop surface of each mapped formation. These, along with digitized 3-D surface polyline and point constraints are used to better align the modelled layers with expert knowledge and mapped geology.

Model development is an iterative cycle of interim model construction, expert geological appraisal to identify errors/inconsistencies in both the model construction and borehole database, followed by editing of formation depth data using geophysical logs, drill cuttings and drill core and a revised lithostratigraphy. Errors in early models were dominated by incorrect borehole location coordinates, data entry errors, and missing and inconsistent formation contact picks, and were expressed as anomalies on modelled formation surfaces.

[2] Carter, T.R., Brunton, F.R., Clark, J., Fortner, L., Freckelton, C., Logan, C., Russell, H.A.J., Somers, M., Sutherland, L., K. Yeung, 2017. 28. Status Report on 3D Geological and Hydrogeological Modelling of the Paleozoic Bedrock of Southern Ontario. Summary of Field Work and Other Activities. 2017, Ontario Geological Survey, Open File Report 6333.

Database integrity and model construction have improved to the point that the current model is approaching a geologically robust result. Issues that have been corrected or are in the process of being delat with include:

- inaccurate thickness extrapolations beneath Lake Huron, to be remedied by addition of Michigan borehole data;
- gaps in continuity of thin formations caused by widely-spaced boreholes, to be remedied by addition of control points with inferred formation depths;
- obsolete stratigraphic terminology in the database has been corrected;
- lack of subdivision of the Lockport Group into its constituent formations has been corrected for 397 wells;
- extrapolations of modelled Silurian formations beyond their erosional limit at the Niagara Escarpment will likely require manual intervention due to functional limitations in the Leapfrog Hydro application;
- incorrect pinchout edges, caused by data gaps, remedied by addition of measured sections and OGS stratigraphic boreholes;
- scattered anomalous outliers for several formations may require manual intervention;
- inconsistent identification of Devonian sandstones, remedied by a separate project to characterize and map the sandstone units;
- inconsistent identification, correlation and integration of the Bois Blanc and Onondaga formations + unnamed sandstone units.

The model is vetted by geologists with many years of experience working in southern Ontario. The model will provide an unprecedented regional perspective and digital framework to support resource exploration, hydrogeological/environmental investigation, education and informed decision-making related to resource management and land-use planning. The model lacks the level of detail needed for a small-scale site-specific investigation, but provides a regional context and may be adapted with the addition of detailed field mapping, new boreholes and structural data.

Using Oil, Gas and Salt Resources Library Well Data in Groundwater Research

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Providing safe drinking water to all Ontarians is increasingly the focus of new regulation and initiatives. Models and studies require high-quality data sources or expensive data collection efforts. Data archived at the Oil, Gas and Salt Resources Library (OGSR Library) represents one possible source of data in groundwater modelling. The OGSR Library dataset has geological and hydrological data for depths in the subsurface that are not intercepted by water and geotechnical borings. This data can be used to create models that extend our knowledge and protection of groundwater deeper into the subsurface.

The OGSR Library is a data archive and geoscience research centre focusing on the data associated with wells drilled under the Oil, Gas, and Salt Resources Act (OGSRA). This data includes files on 26,720 wells (40 Brine, 12,192 Gas Wells, 993 Private Gas Wells, 5,368 Oil Wells, 447 Storage Wells, 207 Solution Mining Wells, 412 Injection and Disposal Wells, 7,061 Other Types). Geophysical logs for 20,430 wells are available, drill cutting samples from 10,887 wells and core samples from 1,110 wells. Geological formation top picks have been recorded for 289,600 contacts, with ~33,861 of these contacts reviewed by QA/QC geologists at the OGSR Library. In addition to these data a huge effort has been undertaken to complete quality assessment and quality control (QA/QC) on the original data from drillers.

In addition to geological and geophysical information there are 35,006 water contact records in the Library database. This data is collected through OGSRA well drilling where the reporting requires details about water interval depths, type, and static level. Detailed water analyses and chemistry are available on 1,023 of the water zones. There can be multiple water records for a single well depending on the number of water intervals encountered during drilling. This allows potential aquifers to be located and mapped for different water types. The use of this data has the capability of greatly improving our understanding of subsurface water at greater depths than other datasets. All detailed well record information can be accessed from the OGSR Library databases with a membership.

A regional 3D geological model of the Paleozoic bedrock of southern Ontario is in its third year of development[1]. This project is a collaboration by the Geological Survey of Canada (GSC), Ontario Geological Survey (OGS), Ontario Ministry of Natural Resources and Forestry (MNRF) and the OGSR Library. The next steps of this project will use the modelled formation layers generated from OGSR Library data to create a hydrostratigraphic model of Southern Ontario. This model represents one application of OGSRA well data to protecting groundwater, many others opportunities are possible.

[1] Carter, T.R., Brunton, F.R., Clark, J., Fortner, L., Freckelton, C., Logan, C., Russell, H.A.J., Somers, M., Sutherland, L., K. Yeung, 2017. 28. Status Report on 3D Geological and Hydrogeological Modelling of the Paleozoic Bedrock of Southern Ontario. Summary of Field Work and Other Activities. 2017, Ontario Geological Survey, Open File Report 6333.

Optimal Use of Source Water Protection Modelling Results

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The Source Water Protection (SWP) Program, with the purpose of protecting the surface or groundwater that supplies municipal drinking water systems, has been managing the development of water resources numerical models at various conservation authorities (CAs). For the Central Lake Ontario Conservation Authority (CLCOA), groundwater models have been developed to support work under Oak Ridges Moraine Conservation Plan (2001), the Clean Water Act (2006) and CLOCA's watershed management program. CLOCA analyzed each dataset and grid results for optimum use in source protection as well as other CA programs. The grid results were used to calculate water balance for various purposes such as watershed management planning, development plan reviews, and opportunities for low impact developments. Reverse particle tracking path lines provided information to identify the natural and ecological features that could potentially be impacted by proposed developments and/or land use changes. Other vital grids and theme maps utilized include, but are not limited to, groundwater discharge to streams, ecologically significant groundwater recharge areas and highly vulnerable aquifers.

In the absence of wellhead protection areas (WHPA) within its jurisdiction, CLOCA has determined that the numerical model development instituted under the SWP Program has more utility for purposes beyond the initial objective of the program. The numerical model products serve as additional science-based planning tools that are defensible for CA to manage and protect the water resources within its watershed.

The Bells Corner Borehole Geophysical Calibration Facility of the Geological Survey of Canada

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Calibration sites provide important opportunities for the standardization of downhole instrument response. Using quantitative physical properties from borehole cores, calibration adds value to projects by allowing for data consistency from hole-to-hole, system-to-system, and importantly, over time. The Geological Survey of Canada (GSC) maintains the Bells Corners Calibration Facilities near Ottawa, Canada, which is available to all members of the geophysical logging community.

In the late 1970's and early 1980's, the GSC developed quantitative borehole calibration facilities, consisting of model calibration boreholes for gamma-ray spectral logging probes with known concentrations of potassium (K), uranium (U), and thorium (Th), density calibration blocks for gamma-gamma tools, and six deep boreholes in Palaeozoic sedimentary (sandstone, dolomite, shale) and Precambrian (granitic) bedrock. The deep boreholes were continuously cored, range in depth from 120 – 300 m, and are sited within a 10 to 100 m triangular configuration for cross-hole capabilities. The published downhole log suite includes spectral gamma-ray, density, neutron, induced polarization (IP), self potential (SP), resistivity, acoustic velocity, magnetic susceptibility, and fluid temperature. In recent years, new GSC calibration datasets have been collected in these wells including high-resolution televiewer imaging, acoustic velocities, and high-resolution temperature and fluid conductivity.

An effort is underway to update downhole and petrophysical core measurements, maintain standardization for traditional downhole instruments, and conduct demonstration projects with newly developed downhole instruments so that sites remain relevant to members of the groundwater, geotechnical, and extractive sectors.

Pinning Down Demand for Groundwater Geoscience: From Narratives to Numbers

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Indigenous people require fit-for-purpose groundwater-surface water data to help First Nations strengthen the federal legislation governing the requirements of safe drinking water for First Nations On-Reserve.

Prior to the 2009-2011 *National Assessment of First Nations Water and Wastewater Systems*, there was no nationally representative data on First Nations On Reserve groundwater geoscience. Currently, this rudimentary baseline report suggests that 158 water systems serve 115 Ontario First Nations. Within this, there are 94 surface water systems, 39 groundwater systems and 13 groundwater-under-the-direct-influence-of-surface-water systems. Ironically, the application of Province of Ontario regulations (such as the Provincial Policy Statement) to Reserve lands are viewed as best practice. Federal government water system policy and practice is not regulated and enforced. Rather, it is also viewed as best practice. This fragmented jurisdiction issue has direct implications to First Nations (FN) On-Reserve who rely on informal water management systems. Against this backdrop, FN must compete for special project, private or charitable funding sources to generate the science required to protect their drinking water sources.

This study has a twofold intent: a) determine how publically funded geoscience providers could meet the groundwater geoscience information needs of 27 First Nations (FN) in Ontario Source Protection Regions; and, b) work with FN stakeholders to refine direction for future funding decisions that may protect raw water sources from threats to water and wastewater systems. Methods used included secondary data analysis, interviews with stakeholders (email, telephone and face to face) and focus groups, case study of water security service delivery review, and review of academic articles and primary documents (FN task forces, workshop and symposium reports).

Factors examined included:

Five different schools of thought around Ontario source water protection (SWP) planning.

The competition and concentration trends within the Southern Ontario source water protection plan (SWP) industry.

Progressively deepening communication gaps between well funded geoscience providers and Ontario First Nations South of 60 (who have pressing SWP geoscience information needs that are unique to First Nations On-Reserve rather than urban Canadians. Currently – 74 First Nations' On-Reserve live with ***boil advisory alert***, and 7 First Nations live with ***do not drink*** advisories). Unfortunately First Nations On-Reserve within Ontario Source Protection Regions have not been working closely with geoscience providers (i.e. 36 Regional Conservation Authorities mandated to develop watershed SWP in 19 Source Protection Regions).

This preliminary report provides some direction for future groundwater/source water research, education and outreach with Indigenous people in Canada. According to our project *First Nations' On-Reserve Source Water Protection in Ontario Source Protection Regions* there is an emerging need for geoscientists to: a) work with Indigenous technical services; b) to speak and understand an Indigenous language; and c) to grow the Indigenous capacity to interpret and apply aquifer-groundwater-surface water data. Encouraging Indigenous people's participation in groundwater geoscience is an opportunity that federal, provincial and municipal institutions should grasp. Building such efforts may provide 27 First Nations in Ontario Source Protection Regions with future On-Reserve-context-specific aquifer-groundwater-surface water data integration and risk analysis.

The Ambient Groundwater Geochemistry Program: Pilot Project in Northern Ontario Precambrian Aquifers

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The first implementation of the Ambient Groundwater Geochemistry Program (AGGP) in northern Ontario was completed in 2016 in the Sudbury area. The Sudbury program was designed to test if the AGGP could be successful in delineating the effect, on groundwater chemistry, of host rock lithology in northern Precambrian shield aquifers as has been already demonstrated for Paleozoic aquifers of southern Ontario. A second objective of this project was to test the potential for the routine sampling of radiological and radiochemical parameters, including radon and gross alpha-particle and gross beta-particle activity concentrations. Since 2016, the focus of the project has been analyzing the data from the Sudbury area survey and completing a 2017 follow-up project along the north shore of Lake Huron, including Manitoulin Island. In total, 93 overburden and 246 bedrock wells were sampled. This poster illustrates the regional trends and groundwater characteristics observed in the AGGP northern Ontario data thus far.

In general, the data indicate fewer water quality related exceedences in the Sudbury area than were observed in southern Ontario. However, a few elements increase in concentration in the Precambrian aquifers of the Sudbury area such as U and Cd. Regional variation in groundwater chemistry was observed and may be controlled by the Precambrian geologic provinces. Bedrock well data from the Grenville Province indicate higher Ca, K and U concentrations than samples north of the Grenville Front. Samples from rocks of the Huronian Supergroup and the Sudbury Basin show relatively high Co, As, Pb and Cu concentrations compared to the Grenville Province. Radioactivity parameters appear to be controlled by the presence of clay rich overburden units rather than bedrock geology.

The samples taken from wells that penetrate clay overburden are more alkaline because these older, deeper waters are disconnected from lower pH surface waters. Groundwater samples indicating a road salt NaCl source, as indicated by Cl-Br ratios, have the highest average dissolved oxygen percentage and total coliform relative frequency suggesting interaction with the surface. Some high chloride waters were noted on Manitoulin Island related to connate water in Paleozoic rocks. Future work on Precambrian aquifers will seek to determine if regional geochemical signatures are controlled by lithology, traces of deep formational waters, anthropogenic influences, or smaller scale regional geologic features such as the Sudbury Igneous Complex and associated mineralization.

Public Access to U.S. Geological Survey Publications and Digital Data

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Since its inception, the U.S. Geological Survey (USGS) has been committed to providing public access to scientific results and data generated from unclassified research funded wholly or in part by USGS. In 2016, USGS took the additional step of institutionalizing its open data practices with a formal Open Data Policy. This policy requires the packaging and cataloging of scientific results and data such that they are discoverable, accessible and digestible by all users (e.g. developers, researchers, citizens).

The USGS Publications Warehouse (**https://pubs.er.usgs.gov/**) is the online citation index for all USGS-authored publications and serves as the authoritative source for information and access to USGS publications. USGS-funded research in external publications also is discoverable through the Publications Warehouse and is now made public not more than twelve months after the initial publication date. The Publications Warehouse site is built in such a way as to allow easy indexing by web search crawlers, and provides both basic and advanced search capabilities. It also provides a number of different Web services, including a customizable RSS feed and a MODs XML service.

The Open Data Policy stipulates that USGS data are published coincident with and separate from any scholarly publication. There is no embargo period for data associated with USGS-authored or funded publications, including publications in scientific journals; the data are made freely available as of the initial publication date.

USGS Science Data Catalog (**https://data.usgs.gov/**) is the public search and discovery tool for fully documented USGS data. The Catalog has greatly improved the ability of the public to locate and access machine readable and downloadable versions of USGS data and metadata since it was created in 2013. The data themselves are stored in one of many USGS trusted repositories, including: ScienceBase—the Bureau-wide repository and collaborative data management platform; the Water National Spatial Data Infrastructure Node that houses many place-based spatial data assets; and Program-specific repositories, such as the National Water Information System (NWIS). Datasets listed in the USGS Science Data Catalog are linked with associated publications accessible through the USGS Publications Warehouse via Digital Object Identifiers (DOI).

Examples of discoverable, accessible and digestible USGS scientific results and data with relevance to Great Lakes Basin groundwater in the United States include:

- Hydrogeologic framework of the glacial aquifer system.
- Groundwater levels in the glacial aquifer system.
- Water quality in the glacial aquifer system.
- Domestic well locations and populations served.
- Input and output files for models published since October 1, 2016.
- Borehole geophysical logs.

A Fully Integrated Groundwater – Surface-water Modelling Platform for Southern Ontario

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Encompassing a land area of approximately 80,000 km^2, the sedimentary basin that lies within Southern Ontario, holds groundwater and surface water resources crucial to both the sustainability and the future development of this nationally important economic and agricultural region. While future water resource availability within Southern Ontario is of obvious concern, both the groundwater and surface water flow systems act as transport pathways for a suite of potential contaminants sourced from waste water treatment plants, industry, and agriculture to reach the Great Lakes. It is also widely recognized that the Great Lakes are under stress, and are now the focal point of numerous provincial, national, and international initiatives to promote surface water quality. These types of water resources challenges are not unique to Ontario, and world-wide there is a growing need to utilize 'big data' and advanced technology to help quantify and understand the risks faced by our global water resources. In this context, efforts underway in Southern Ontario are leading to the development of a globally 'best-in-class' water resources characterization, quantification, and risk management modelling platform.

The Southern Ontario model is currently being constructed with the HydroGeoSphere (HGS) platform, a 3D fully integrated groundwater – surface-water (GW-SW) flow and transport simulator. When completed, the model will incorporate several million computational nodes in a high-resolution 3D unstructured finite element mesh, and will facilitate dynamic representation of GW-SW interactions with daily temporal resolution. Development of a model of this scale and complexity is facilitated by ongoing advances in numerical methods, and by the increasing availability of detailed geological, hydrological and land surface datasets that are required when simulating such an expansive model domain. In particular, the recent development of a 60 layer bedrock lithostratigraphic model for Southern Ontario, and the contiguous quaternary hydrostratigraphic data, have made the task of characterizing the subsurface component of the model manageable. When combined with existing highly detailed soils, land cover, and hydrology data, as well as data from the Province's network of surface water and groundwater hydrometric monitoring stations, the hydrostratigraphic data will support an unprecedented level of detail within such a large, regional-scale integrated model. We will present the physical framework of the 3D Southern Ontario HGS model, the principle data sets that are being employed, and the development progress to-date.

It is anticipated that this proof-of-concept modelling platform will serve a strategic array of objectives, including the provision of regional boundary conditions for local scale models, and assessments of:

- Climate change impacts on surface water and groundwater resources;
- Surface water and groundwater stresses induced by population growth;
- Impact of large-scale water extraction on regional flow systems;
- Cumulative impact of agricultural nutrient and WWTP effluent on Great Lake water quality.

Near Surface Seismic Database: Future Online GSC Data Delivery

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The near surface geophysics group at the Geological Survey of Canada (GSC) has developed a land streamer system for the rapid acquisitions of seismic data. With this system, over 700km of near surface seismic data has been collected over the last decade, and the data collection is rapidly growing.

Using Microsoft Access a database has been designed to catalogue these projects and the associated processed seismic sections, with ease of upkeep as a priority. To accomplish this, a library of Access Macros was created to make data entry as efficient as possible.

With the macros working in the background, a new survey is added to the database in a few minutes. When a project is entered, the associated files are automatically copied into a backend file structure, creating a consistent and organized backup of the processed seismic lines, their coordinate files, and the log sheets. Macros automatically generate and store links to these files in the database. Storing the archived data as links rather than attachments keeps the database below the file size limit of 2GB without losing file accessibility. Additionally, the relevant spatial meta-data (such as survey boundaries in UTM and Latitude-Longitude coordinates) are extracted automatically, instead of having the user sift through and manually enter this data.

Additional meta-data is entered manually, such as survey description, acquisition and processing parameters. Meta-data is important as it provides the user with critical information that supports analysis and interpretation of the survey results. The GSC is committed to the ISO 19115 metadata standard and all published data has to be fully compliant with the Federal Geospatial Platform Harmonized North America Profile (FGP HNAP) metadata profile (**http://www.nrcan.gc.ca/earth-sciences/geomatics/canadas-spatial-data-infrastructure/geospatial-communities/federal**).

Survey coordinates can be exported from the database as KML files, making them compatible with Google Earth. This is useful for quality control and spatial querying as eventually this database will form the backbone of an internet accessible tool to search, view and download near surface seismic profiles in SEGY format, which is a proprietary SEG industry standard. It will be much easier to access data from a standardized structure at one location rather than independent Open Files. This is expected to help applied geo-scientists and researchers integrate this information into their work. This project aligns with the Government of Canada Open Data policy and delivery within a searchable online mechanism (**http://open.canada.ca/en/open-data**).

The Use of Wide Spectrum Groundwater Geochemistry in Regional Groundwater Mapping in Ontario

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Groundwater geochemistry is increasingly being recognized as a valuable tool in regional characterization of aquifer systems. In support of such investigations, the OGS has developed and maintains the Ambient Groundwater Geochemistry (AGG) database, which characterizes groundwater across a wide spectrum of chemical and isotopic parameters at near-uniform regional sample coverage. The original stated objective of the program was to determine the chemical composition of groundwater in Ontario's major rock and overburden aquifers to understand the relationship between water chemistry and aquifer chemistry. However, it was recognized from the outset that the database would have additional uses, and this has proven to be the case many times over. Since 2007, data from the AGG program has formed the basis of 15 separate OGS-supported regional studies on groundwater mapping-related themes. Many of these have been graduate theses and most include regional characterization and mapping of phenomena such as: (1) shale gas occurrence, (2) breathing wells, (3) buried karst, (4) natural contaminants in groundwater (arsenic, fluoride, iodine, methane, hydrogen sulphide, etc.), (5) the chemical effects of buried valleys and marine sediments in eastern Ontario, and (6) tritium fallout patterns in southern Ontario. The regional effects of various anthropogenic influences on groundwater chemistry have also been noted including the chemical effects of overpumping of aquifers, legacy gas wells, road salt application, and septic and agricultural influences.

The data have been publically accessible since 2011 and we are aware that it has also been put to use in many independent studies by researchers in private industry, academia and government. As with other OGS products such as geological maps, the AGG database is available for use by any public stakeholder and is likely to remain a valuable public asset into the foreseeable future.

Numerical Modelling – A Key Tool to Support Water Management Decisions in Ontario

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Since about 2000, Ontario's municipalities, conservation authorities, provincial ministries and consulting firms have been variously engaged in preparing technically sophisticated numerical models for the purposes of managing and protecting water supplies. Not only have these models led to an improved understanding of water quantity and water movement within the province's watersheds, but the work has also led to a comprehensive synthesis of water related information across much of the province.

A resultant ongoing challenge for all parties is one of maintaining this new knowledge based infrastructure for future use. The challenge is a difficult one, in light both of the limited finances, as well as the limited technical modelling expertise available within the province. However to not make use and build upon the important work that has been undertaken, would be a disservice to Ontario's citizens. It is therefore incumbent on the community of practitioners to figure out a strategic path forward.

The goal of this half-day session will be to initially shed light on the ability of numerical models to provide insights into flow system behaviour and thereby be a valuable tool for water resources management. The follow up panel discussion will touch upon various issues related to broadening the use of numerical models. One specific topic of interest will be model management, this being a very new endeavour, having only recently arrived at Ontario's doorstep in a significant way following on the extensive technical work undertaken through Source Water Protection.

Through the construction and use of numerical models, consultants assemble a tremendous understanding of the how water moves in the subsurface and how it interacts with the surface water environment. The entirety of this understanding can never be fully conveyed in a summary report. Drawing upon their considerable expertise in the construction and use of numerical models, the speakers will highlight various instances where numerical models have been used, or could be used, to reveal flow system behaviours that can assist Ontario to improve water management related decisions.

Following upon the talks, stick around after the break for an engaging and insightful panel discussion that will address a broad range of current issues surrounding the use of numerical models in water management decision-making. Can any numerical model be re-used/re-purposed for future decision-making given that it has been built for a specific purpose? Should models be considered out dated and obsolete once they have served their initial purpose? What are the limitations to such re-use and how should they be conveyed? Is it that only certain elements of a numerical model be used into the future? Who should ensure models are up-to-date and reflect the most current understanding prior to their re-use? How can high level technical and policy managers be made aware of the considerable insights that numerical models can bring to bear on water management decisions? As a community of

technical practitioners, is there a need to train colleagues and staff at provincial ministries, municipalities, conservation authorities and consulting firms, to be more comfortable with the insights and analyses offered up through numerical modeling? How is this best achieved? Will this lead to increased use of numerical models as a key input to guide decision making? Is there perhaps a role for a structured peer review system whereby credible modelling experts are retained to assist in model re-use/re-purposing?

Newmarket Till Aquitard: Optimum Grain Packing with a Pore-filling Calcite-rich Cement

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Newmarket Till is a stoney, sandy (38%) silty (~47%) diamicton, which is of variable thickness (~1 – 69 m) and of widespread distribution in Southern Ontario. The Newmarket Till has unusually high densities (2.2 – 2.4 g/cm^3); elevated seismic velocities (Vp ~2600 m/s) determined by downhole geophysical studies are characteristic and the Till can be traced across the region as a seismostratigraphic marker. As the Till is highly indurated and has low permeability, it forms a regional aquitard that confines underlying aquifers, and is also a basal aquitard for overlying aquifers (e.g. Oak Ridges Moraine). Given the high sand content of this diamicton, the low permeability and indurated nature is surprising, and could be resultant from over-consolidation due to glacial loading, presence of a secondary cement, or both processes.

Recent observations from drill core and surficial sampling transects illustrate that Newmarket Till is not always cemented, but the observation of residual cement on pebbles indicates it was potentially formerly cemented. Our new studies indicate that the matrix of the Dummer moraine (adjacent to and south of the Shield – Paleozoic boundary and to the north of the Newmarket Till) is mineralogically and geochemically equivalent to Newmarket Till, and we thus suggest the Dummer Moraine is a very stone- to boulder-rich equivalent of the Newmarket Till. The matrix mineral assemblage of the Till (in decreasing abundance) is quartz, calcite, K-feldspar, plagioclase, dolomite, amphibole and clinopyroxene; these grains are comminuted and range in size from ~2000 µm to ~2 µm, leading to optimum packing, and potentially over-consolidation. The intra-grain matrix is exceptionally fine (<1 µm, typically 0.25 – 0.50 µm) and not resolvable by optical methods. Higher resolution SEM and FE-SEM backscattered electron and secondary electron images of the intra-grain matrix reveals a complex pore filling cement. The minerals comprising the secondary cement are a challenge to analyze due to their very fine grain size and composition. Semi-quantitative EDS analyses indicate a calcite ($CaCO_3$) cement with minor phyllosilicates, as confirmed by XRD on the clay-silt and clay fractions. The calcite cements the silt- to sand-sized mineral grains and larger clasts, and result in the Newmarket Till being highly indurated and of low permeability. The timing and process of the initial cementation event is currently being evaluated; we also note that in the vadose zone the Till becomes uncemented (i.e. the original calcite cement dissolves out).

A Chemostratigraphic Framework for Southern Ontario: A Progress Report

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Work has been advancing since 2015 on the development of a framework and reconnaissance scale overview of subsurface geochemical variability of southern Ontario. In a collaborative effort between universities, Conservation Authorities, the Ontario Geological Survey and the Geological Survey of Canada geochemical data is being acquired from continuously cored boreholes using both portable X ray fluorescence spectrometry and traditional wet chemical analysis. The activity is now in its third year and recent work has focused on sediment cores from the GTA, Waterloo, Dundas Valley, Bradford, south Simcoe, and London areas. Thirty-three boreholes and ~3000 samples have been analyzed. The borehole distribution loosely aligns alon and east-west and north- south transect of 300 and 200 kms, respectively. All data is in the process of being prepared for publication as data release Open Files. An additional ~600 samples have been received from Oro, Orangeville, Niagara, and Pickering areas and analysis should be completed in 2018. These analysis will complete the reconnaissance scale transect framework development for Southern Ontario. Once finished, the framework will be available for comparison when more site specific, local scale studies obtain subsurface geochemistry.

Work is also underway preparing a manuscript on the methodology and QA/QC process employed within the southern Ontario project for the combined laboratory and pXRF dataset.

Downscaling SMOS/SMAP Soil Moisture Product Using Radarsat Constellation Mission (RCM) Data: A Case Study in Southern Ontario

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Current soil moisture products derived from SMOS and SMAP satellites have very coarse resolutions (~40km). This limits the soil moisture products for applications where a resolution of 1-10 km is generally needed (e.g. hydro-climatological applications). To obtain high resolution soil moisture, an algorithm was developed to downscale SMOS/SMAP products by using multi-temporal dual-polarized (HH and HV) C-band SAR images. Recently the use of full-polarized (FP) SAR data was reported to improve soil moisture retrieval even under dense vegetation canopy, but FP SAR data has the disadvantage of narrow swath, which limits its applications for soil moisture estimates over large areas. With the Radarsat Constellation Mission (RCM) becoming operational in 2018, it will provide compact polarimetric (CP) configurations that has a wider swath and hence is a possible alterative to the FP data. A new downscaling algorithm has been developed to improve soil moisture retrieval by using RCM-CP data, which is simulated from the Radarsat-2 FP imagery. Comparing to previous algorithm, the new algorithm can enhance the removal of vegetation effect by using a normalized scattering based empirical model, in which the conditions of vegetation are characterized by the RCM-CP derived vegetation parameter. In addition, a new mathematical model, rather than complicate wavelet transform, is used to better account for scale change. The new algorithm is validated with in-situ soil moisture data from Southern Ontario collected in the summer of 2017. When compared to results obtained from a previous algorithm there is a promising improvement in soil moisture estimation. Since the RCM will provide a short revisit time (<4 days), this study demonstrates the potential for fusing RCM data with SMOS/SMAP soil moisture (2-3 days repeat cycle) to continuously map soil moisture at higher resolutions over large areas, even under dense vegetation.

Low Temperature Geothermal Case Studies

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Ontario supports "green" heating and cooling sources, such as geothermal systems, and is committed to ensuring the safe installation of these systems to protect human health and the environment. Consequently, the use of geothermal systems is expected to increase. Over the next decade, installations of geothermal systems will become routine and common, especially systems using deeper boreholes in dense urban areas. If not properly constructed and managed, there is a potential for geothermal systems to impact groundwater and surface water sources as well as present human health and public safety issues. The Ministry of the Environment and Climate Change will present some examples of incidents that ministry has responded to and mitigated over the last ten years.

Update on COA and GLWQA Groundwater Activities

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The Canada-Ontario Agreement (COA) on Great Lakes Water Quality and Ecosystem Health (2014) is the 5 year federal-provincial agreement to help meet Canada's obligations under the Canada-US Great Lakes Water Quality Agreement (GLWQA). The first goal of COA Annex 8 Groundwater Quality is to gain a better understanding of how groundwater influences Great Lakes water quality and ecosystem health, and to identify priority areas for research and investigation. The COA commitment to meet this goal included Ontario and Canada working with the United States to develop the state of groundwater science report.

Groundwater science relevant to the Great Lakes Water Quality Agreement: A status report was released in May 2016 and is available on **www.binational.net**. The report is a product of collaboration among groundwater experts from both countries and summarizes current knowledge on groundwater and identifies science needs to better understand the role of groundwater in the Great Lakes Basin.

The short term (2017-2019) science needs that were identified by the Annex 8 team include:

1: Develop better tools to assess groundwater – surface water interaction and use them to advance assessment of regional-scale groundwater discharge (quantity) to surface water in the Great Lakes Basin

2: Establish science-based priorities to advance the assessment of the geographic distribution of known and potential sources of groundwater contaminants relevant to Great Lakes water quality, and the efficacy of mitigation efforts.

3: Advance monitoring, surveillance, and assessment of groundwater quality in the Great Lakes Basin.

Ontario funded COA projects that address the short term science needs for groundwater are described. The University of Guelph is developing an integrated groundwater-surface water model that is based on the extensive water and climate data from a COA funded integrated water and climate monitoring station. The current water cycle and future water cycles under various climate scenarios will be investigated.

The Provincial Geomatics Services Centre has identified over 150 databases and inventories of potential point sources of groundwater contamination in southern Ontario. The development of a methodology to assess the results will be developed by COA Annex 8 team.

The GLWQA Annex 8 team was involved with developing the Groundwater Quality Subindicator under GLWQA Science Annex 10. Using concentrations of common groundwater contaminants chloride and nitrate an assessment of groundwater quality in the Great Lakes Basin was conducted for the first time.

Enhancing Flood and Drought Forecasting Tools in the South Nation River Watershed

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With climate change, managing the variability in changing watershed conditions, from floods to droughts, is a challenge. Having the necessary information, in a timely manner, is critical for proper planning and implementing mitigating measures.

South Nation Conservation's (SNC) recent project with IBM and Aquanty, the development of a data-assimilation and hydrological simulation platform, aims to improve short term (1 – 14 d) forecasting of flooding and droughts. The project will construct a real-time hydrologic model for South Nation Watershed. This fully integrated 3-dimensional groundwater – surface water model is dynamically coupled to state-of-the-art high resolution (4000 m) short-term weather forecasts (provided by IBM's Weather Company) and real-time field sensors throughout the Watershed.

The model will enhance SNC's Flood Forecasting and Warning and Low Water Response programs with more accurate forecasts; utilizing over 200 local weather data points (compared to the previous 3 Environment Canada stations) to capture the diversity of weather patterns across the Watershed. The new real-time sensors to collect precipitation (rain and snow) and soil moisture will allow the model to better predict how forecasted weather events will impact watershed conditions. For example, is a significant rainfall event more likely to runoff into nearby watercourses or soak into the ground.

Beyond its direct application to the South Nation Watershed, this project will provide a proof-of-concept demonstration of how the latest in weather forecasting and hydrologic modelling technologies can support water resources management under increasingly variable climate/weather conditions. It is anticipated that this project will provide far-reaching benefit to SNC, local producers, municipalities, and rural landowners throughout the region

This project was made possible with funding support from Agriculture and Agri-Food Canada.

Quaternary Geology and Hydrostratigraphy of the Central Simcoe County Area, Southern Ontario

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The population of communities bordering southern Ontario's greenbelt is increasing. Effective growth plans require an understanding of the state of regional water resources and groundwater flow systems. To address these needs, the Ontario Geological Survey (OGS) initiated a three-dimensional (3D) sediment mapping investigation in the central part of Simcoe County in 2014 to help provide the regional context and necessary geoscience data to guide planning and resource management decisions. OGS 3D sediment mapping studies aim to characterize the architecture of Quaternary sediments, better define bedrock topography, delineate potential recharge areas and aquifer extents, and identify potential surface water–groundwater interactions.

Surficial mapping from 2014-2016 assisted in establishing sediment properties and variability, refining the shallow subsurface sediment architecture, and developing an understanding of shallow groundwater flow systems in the region. A regional gravity survey was undertaken in 2014 to improve the understanding of the bedrock topography beneath thick drift underlying the study area. Seismic reflection surveys carried out by the Geological Survey of Canada in 2015 and 2016 assist in delineating the architecture and facies variability of Quaternary sediments and bedrock. Sediment drilling programs conducted in 2015, 2016 and 2017 have produced 26 continuously-cored boreholes. Additional boreholes from previous OGS mapping (5) and other geologic investigations (2) bring the total number of cored boreholes in the study area to 33. Most boreholes (26) reach bedrock and, in many cases, are the only sources of information on the deeper subsurface geology within several kilometers.

Four major sediment packages characterize the Quaternary stratigraphy overlying Paleozoic and Precambrian bedrock in the study area. In ascending order, these include: older tills and glaciolacustrine deposits, Thorncliffe Formation equivalents, Newmarket Till, and postglacial deposits. Seismic data assist in deconstructing complex architectural and facies relationships observed within the major packages. Downhole geophysical data provides necessary ground-truth and an improved understanding of the variability of physical properties of regional sediment units at borehole locations.

Significant aquifers are encountered at various intervals within each major sediment package except the Newmarket Till, which forms a surficial and subsurface leaky aquitard throughout the region. To support efforts to delineate groundwater recharge areas and identify major flow systems, 17 boreholes have been converted into monitoring wells in collaboration with local conservation authorities, municipalities and associations for long-term analysis of groundwater levels. In addition, a new initiative by the OGS, with field programs beginning in 2018, aims to integrate additional hydrogeological characterization with the geologic and geophysical data associated with 3D sediment mapping. This hydrogeological characterization will comprise groundwater sampling and chemical analyses, following the protocols of the OGS ambient groundwater geochemistry program, as well as the integrated analysis of in-situ pumping tests and hydrologic information from high-quality boreholes and local water well records to better understand the properties of aquifers beyond the borehole sites.

Preliminary results indicate that refinement of the existing hydrostratigraphic framework is required for the region. The new data will provide additional constraints on the function and properties of regional aquitards, the stratigraphic setting and hydrochemistry of producing aquifer zones, the occurrence and geometry of previously unidentified aquifer, long-term climatic fluctuations and water level responses in the Great Lakes basins.

The Ontario Geological Survey's Groundwater Initiative: Deliverables, Data, Derivatives and Future Direction

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Regional mapping investigations by the Ontario Geological Survey (OGS) to support groundwater studies in southern Ontario have expanded significantly since 2001. The OGS groundwater initiative involves the collection and dissemination of high-quality geoscience data to enhance characterization of the subsurface through the execution of three mapping activities; 3-D Paleozoic bedrock mapping, 3-D Quaternary sediment mapping, and ambient groundwater geochemistry mapping.

3-D Paleozoic bedrock mapping studies aim to characterize and delineate stratigraphic units that host aquifers and control local and regional bedrock groundwater flow systems. Mapping, drilling and collaborative investigations in Silurian strata along the Niagara Escarpment (including 397 boreholes) have led to an improved understanding of the occurrence, connectivity and genesis of karst systems as well as the hydraulic properties of these bedrock flow systems (GRS16). Integrative studies have also supported the mapping of groundwater recharge areas and chemical evolution profiles (MRD337) for key hydrostratigraphic units. The next phase of study involves mapping bedrock units, buried cuestas and bedrock potable groundwater flow zones in upper Silurian to Middle Devonian strata of southwestern Ontario.

3-D Quaternary sediment mapping investigations produce 3-D models of regional-scale stratigraphic units. The models aid in hydrostratigraphic assessment and correlation of sediment units as well as the delineation of potential recharge areas and a better understanding of surface water–groundwater interactions. Projects are complete in Waterloo (GRS03), Brantford-Woodstock (GRS10), Barrie-Oro (GRS11), and Orangeville-Fergus (GRS15). Borehole data collected for the South Simcoe area is available (MRD324) and model construction is nearing completion. Geophysical data collected by the Geological Survey of Canada to support ongoing mapping in the Niagara (MRD353) and south and central Simcoe areas are available (GSC OF8251; 7883; 8252). Results from 3-D sediment mapping projects have produced a database of subsurface information from >350 boreholes in southern Ontario.

The ambient groundwater geochemistry project provides an improved understanding of the relationships between groundwater chemistry and the composition of aquifers in southern Ontario, as well as insights on the flow evolution, residence time, and vulnerability of groundwater systems, through the collection and analysis of untreated bedrock- and overburden-derived groundwater at >1850 locations (MRD283-REV). Ambient geochemistry data have led to the identification of multiple natural and anthropogenic factors locally affecting groundwater quality in the province. Derivative products include improved characterization and delineation of rapid recharge areas and subsurface karst terrain. Ongoing work has shifted focus to Ontario's near-north, from Manitoulin Island eastward to the North Bay area.

In the future, the groundwater initiative aims to enhance integration of its three core activities thereby providing a holistic approach to assessments of the provincial groundwater resource. Continued investigations will allow for the synthesis of information from individual regional studies to scales suitable for the analysis across multiple watersheds and possibly at the scale of the Great Lakes drainage basin.

Co-existence of Industrial Organic Contaminant Plumes with Municipal Water Supply Wells in Fractured Rock Aquifers

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Long-term studies combining research and conventional methods are being conducted at DNAPL sites where the organic contaminant plumes co-exist in the same fractured sedimentary rock aquifer with municipal water supply wells. Two of the research sites overlay the horizontally layered, Silurian dolostone aquifer. The Cambridge site has a metolachlor pesticide plume detected nearly 1 km down-gradient at a municipal supply well 20 years after spills occurred. The Guelph site plume is TCE. The plumes were characterized in detail using high-resolution methods for identifying hydraulically active fractures and variable matrix conditions. The 3-D plume concentration characteristics have been monitored for more than a decade using depth-discrete multilevel systems. The plumes have evolved to nearly stationary position (steady-state) after three decades due to the combined effects of diffusion and sorption in the matrix with dispersion in a dense network of well-connected fractures. Degradation occurs in each of the plumes but is a secondary factor in terms of current plume extents. These research studies show that high resolution monitoring can be used to inform site conceptual models and decision-making by municipalities and regulatory agencies to allow these plumes to coexist within or proximal to municipal or private well fields without imposing excessive or arbitrary demands for subsurface source removal (i.e. remediation) or well abandonment.

Investigation of the Potsdam Group Sandstone Aquifer Vulnerability with the DFN-M Approach

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As cities grow, surrounding rural communities often experience development stresses such as increased demand on local aquifers. Rural aquifers can have different threats than city centres, such as nitrates from agriculture or pathogens related to septic systems that may not have historically been a dominant concern, but become so under the increased water demands. Case in point is the growing community of Greely, near Ottawa, Ontario which is surrounded by agricultural lands, homes have individual septic systems, and a shallow bedrock aquifer provides the sole water supply from a communal well. The City of Ottawa has engaged the project team to examine the deeper Nepean sandstone as an alternative water supply. An initial borehole was continuously cored through the Paleozoic bedrock sequence into the Precambrian close to the existing pumping well. The detailed Discrete Fracture Network – Matrix (DFN-M) approach was applied including rock core logging, chemical analysis, geophysical logging, hydrogeologic and hydro-geophysical testing, with cross-hole testing pending. We present the study approach, preliminary results and future plans. In addition to dealing with Greely's challenges, the multiple high-resolution data sets provide insight into this complex geologic/hydrogeologic setting and an initial assessment of the sandstone's viability as a water supply elsewhere.

An Integrated Investigation of Groundwater – Surface-water Interactions under Conditions of Changing Climate in the Great Lakes Basin

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Fluctuations in temperature and precipitation associated with changing climate have the potential to influence hydrologic components, such as the timing and amount of groundwater recharge as well as temporal patterns in stream base flow. Variations in such factors may impact ecological functioning and human activities within a watershed, especially in water stressed, agriculturally dominated regions of the Great Lakes Basin. The potential impacts of climate change and subsequent feedback mechanisms are best examined through an integrated monitoring and modelling approach. In this manner, an improved understanding of a watershed's hydro-climatic functioning, especially groundwater–surface water interactions, may be obtained through multi-faceted, field based data collection and further supported by integrated numerical modelling. This research presents the Upper Parkhill Watershed in southwestern, Ontario (jurisdiction of the Ausable Bayfield Conservation Authority) as the location of an ongoing integrated investigation. This watershed features an Integrated Water and Climate Monitoring Station that has been collecting continuous data since 2012. Measurements from this station have been supplemented by site characterization as well as a water sampling program examining groundwater tracers, such as 222-Radon and electrical conductivity, in addition to stable isotopes (18O and 2H) and tritium to respectively assess locations of groundwater discharge, water origin, and age. This research supports the creation of an improved hydrogeologic conceptual model from which groundwater–surface water dynamics will be evaluated in the context of historical and potential future climate variability. It is anticipated that this study will provide a framework for the use of data from integrated monitoring stations and will also help to identify data gaps and variables of greatest importance for the purposes of integrated modelling.

Use of Provincial Data by Conservation Authorities

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Conservation Authorities are local level, water resource management organizations; jurisdictionally defined on the watershed-scale. Both local and regional land use decision making process should be informed by a robust understanding of the geological framework and hydrogeological regime. This requires considerable multi-disciplinary expertise, funding, and an on going involvement by local stakeholders. For our respective conservation authorities, and by extension our municipal partners, the Ontario Geological Survey (OGS) has been the catalyst for local efforts to address data gaps to inform better land use decisions. The use of preliminary data generated from the OGS 3D Geological Model projects in the Niagara Peninsula and Central and South Simcoe areas have addressed information and knowledge gaps including but not limited to: lack of meaningful regional geologic cross-sections; extent and definition of aquifers; buried bedrock channel morphologies; distribution, thickness and composition of aquitards; refinement of Highly Vulnerable Aquifers, and geochemical anomaly characterization. This has been completed through improved hydrogeologic characterization via additional golden spike monitoring locations and baseline monitoring (hydraulic and geochemical), geophysical delineation, and associated modelling.

Early advantages of local utilization of the OGS project results have included the use of geological refinement in the development of an integrated MikeSHE model for drought management; information for rural development approvals and municipal groundwater exploration studies, collaboration on emerging chemicals of concern, and spatially improved groundwater monitoring. Importantly, the OGS results are also addressing items needed for source water protection planning but unavailable for source water protection funding: (i) research to address local data gaps and (ii) long-term water quality monitoring programs.

Chemical and Isotopic Evidence of Fragmented Recharge Areas for the Carbonate Aquifers of the Niagara Escarpment

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The Early Silurian carbonate bedrock formations of the Michigan basin, southern Ontario, contain significant quantities of high-quality groundwater resources and provide the sole drinking water source to many large municipalities and private residences. This investigation represents the first attempt to characterize these carbonate groundwater resources in their entirety. Although the bedrock formations are relatively flat-lying and regionally extensive, suggesting ease of characterization, the systems are complex due to the influence of glacial sediment cover on recharge and the effect of karst on groundwater residence times. Recharge timing and controls are investigated with several isotopic and geochemical indicators of recent recharge in groundwater, within the context of the sedimentary geology and sediment thickness of the study area. Spatial trends of tritium, and SF6 in groundwater, interpreted as representing recent recharge (< 50 years), corroborate with aerobic redox chemistry in the carbonate groundwater systems underlying areas of thin or permeable sediment cover. Groundwater chemical evolution beyond recharge areas is assessed with general chemistry, the redox profile and an investigation of water-rock interaction. A comparison of strontium isotope ratios (87Sr/86Sr) in bedrock and groundwater shows that long residence times are required for the isotopic signature of the rock to imprint on the groundwater. Increasing Sr to Ca ratios along the groundwater flow path are likely resulting from incongruent dissolution of dolomite and the precipitation of calcite with evolution. Sulphur isotopic composition of sulphate (δ34SSO4 and δ18OSO4) in groundwater shows isotopic evidence of pyrite oxidation in recharge areas, and a Silurian sulphur isotopic signature in areas of thick and low permeability sediments, well downgradient of identified recharge areas. For this investigation, isotopic and hydrochemical tools have provided many essential lines of evidence, supporting the development of a conceptual model of recharge and groundwater evolution in this complex setting with many geological controls at play.

The Microvibe, a Broad Band, Light-weight and Cost Effective Seismic Source for Near Surface Imaging

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For shallow environmental and engineering surveys in generally unconsolidated sediment to depths of a few meters to several hundred metres high resolution seismic reflection surveys require heavy and expensive vibration sources such as a Minivib™. It weights 9 tons and costs approximately $400K. Best practice for optimized characterization of shallow surficial properties multi-component acquisition is required and this necessitates multiple passes and recording with the Minivibe – landstreamer system with the source being set in various horizontal and vertical directions. To provide a cheaper and lighter seismic source we have developed the Microvibe (180 kg and ~$30k) uses a suite of lighter electromagnetic transducers that can provide multicomponent seismic signal in a single pass.

The Microvibe consists of forty tactile transducers, twenty per direction, on a solid concrete block mounted on a steel skid plate. This vibrator can provide various types of sweeps from 20 Hz up to 800 Hz with a power up to 2000 watts, for each direction, providing ~25% of the power provided by an IVI Minvib. To compensate for the reduced power level, we increase the time length of the sweep. The Microvibe provides higher frequency ranges than any known land seismic source available on the market.

The Microvibe is coupled with an in-house built landstreamer array designed for use along paved or gravel roads. The landstreamer is built with 3 kg metal sleds connected using straps or low stretch ropes. The receiver spacing can vary from 0.75 m to 3 m. Receiver set-up is customized depending on the near-surface velocities and the targeted depths of observation. Each sled is equipped with a 3-component (3-C) geophone unit constructed in-house with 30 Hz omni-directional geophone elements oriented in three orthogonal directions: one vertical and two horizontal, in-line (parallel to the survey direction) and cross-line (perpendicular to the acquisition direction). The Microvibe – landstreamer combination allows data acquisition with shaking in vertical and horizontal directions in one pass to capture P-wave and S-wave seismic reflection sections.

In order to demonstrate the value of this new geophysical tool, examples will be presented from a ground water example in the Vars – Winchester esker of southeastern Ontario. The system is also very efficient for evaluating the soft soil response for earthquakes and for locating neo-tectonic faults or buried tunnels.

Assessing the Integrity of Aquitards: the Newmarket Till at Ajax

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The Newmarket Till is a regional aquitard in southern Ontario that overlies the Illinoian to Middle Wisconsinan Lower Sediment and is overlain by the Oak Ridges Moraine. Geological investigations have mapped the distribution of the till and it is understood that erosional channels, subsequently infilled with fluvial material, breach the till and may create enhanced hydraulic connection between overlying and underlying aquifers. However, little is known about the protective capability of the Newmarket Till where it is intact. This knowledge gap is being addressed by investigations of the rates and mechanisms for transport of natural and anthropogenic tracers in the porewater of the till. The research program was initiated in October 2017 with the coring of a new borehole at Sideline 4 near the intersection of highways 407 and 412, north of Ajax, Ontario. Vertical concentration profiles are generated for natural tracers by subsampling drill cores and then extracting porewater to measure the chemical (Cl, Br, F, NO_3) and isotopic composition ($\delta^{18}O$, $\delta^{2}H$, $\delta^{13}C$, ^{3}H, $^{3}He/^{4}He$). By coupling the tracer concentration profiles with a one-dimensional numerical transport model, we will calculate the rates of diffusive and advective transport across the aquitard.

Highlights of OGS – GSC Collaboration on Regional Groundwater Studies: 2017 – 2018

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The Ontario Geological Survey and Geological Survey of Canada groundwater collaboration in Southern Ontario is finishing the fourth year of a five year project cycle ending March 31st 2019. Following earlier updates on work completed this summary will be provided under five principal themes.

1. Framework for Sustainable Groundwater Use: The 3D bedrock modelling activity has developed the 5th iteration of the formation level working model. Final QA/QC is being completed during the winter of 2018. An animation on the salient features of the model and viewing options was published. The surficial modelling work has been delayed due to efforts on the bedrock model; however progress is underway and iterative QA/QC on a preliminary 8 layer model is progressing.

2. Supporting Great Lakes Water Accords: Work has advanced on development of a conceptual framework for evaluating groundwater – surface water interactions and impacts on the quality and quantity of water and ecosystems. A contract was awarded for a fully coupled regional numeric groundwater – surface-water "proof-of-concept" model for southern Ontario in the Hydrogeosphere modelling environment.

3. Methods Development for Regional Groundwater Studies: Methods are being advanced through analysis of seismic reflection data processing, and downhole geophysics. A new initiative this year was preliminary work with Nuclear Magnetic Resonance tools. Progress continues on regional methods for soil moisture studies using RadarSat II and SMOS. Work was initiated on a hydrogeophysical study over part of the Vars-Winchester esker to explore the potential extrapolation of hydraulic parameters using high-resolution multi-component seismic data and electrical resistivity data.

4. Case Studies: Data collection has been completed in a number of areas. Sample analysis for the chemostratigraphic framework using samples from continuous core has been expanded to include Dundas Valley, Brantford, and London. A geostatistical approach is being applied to develop a hydraulic parameter estimation for a 3D model of the Innisfil Creek sub-watershed. Characterization of Newmarket Till cementation is ongoing and is being supplemented by porewater chemistry analysis. A range of data consolidation work has been advanced on GSC, OGS datasets and technical reports related to municipal wells and aquifers contributed by conservation authorities. Work is ongoing on the hydrostratigraphic classification of wells within the PGMN with most monitors screened in surficial deposits having received a preliminary classification.

5. Science and Technology Exchange: Manuscript submission is finished for a special issue of Canadian Journal of Earth Sciences with 8 published articles and 3 manuscripts in review. Project results are available via OGS – GSC publication streams, conference proceedings, and journal publications. Three overview documents on bedrock modelling, chemostratigraphy, and data consolidation were published in the Ontario Geological Survey Report of Field Work and Other Activities for 2017.

An Animation of the 3D Phanerozoic Geological Model of Southern Ontario

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A preliminary 3D model of the Paleozoic bedrock geology of southern Ontario has been constructed using Leapfrog implicit modelling software, subsurface geological data and expert knowledge. With advances in computer hardware and software, and availability of digital well and drillhole databases it is now possible to model and visualize subsurface geological relationships in 3D at regional scales. This is a valuable tool for geologists in interpreting and understanding the geology and geological history of an area, and for communication of geological concepts to non-geologists. In the virtual visualization environment, the geology can be examined from a number of perspectives interactively. The stratigraphic succession and boundary geometry can be identified by either progressive removal of units or cross-section slicing. In the southern Ontario model features that can be viewed and studied include depositional and erosional limits, reefs, faults, salt dissolution and collapse structures, regional dips, arches, depositional and structural basins, oil and gas traps, and regional aquifers.

To increase the visibility of this model and to expand the audience beyond the technical geological client group an animation of the model has been produced. The animation is approximately three minute and thirty seconds long and provides a systematic progression through the model units, provides regional context, an overview to the data support, and illustration and explanation of geological features. Selected geological features are presented and highlighted through graphic techniques supported by embedded imagery, annotations, animations and maps. It previews the shareware viewing software available for viewing of the model and highlights some of the tools available for interacting with the model.

Communication of geoscience knowledge to audiences outside of the core geoscience community is key to support groundwater related decision-making. The animation has been released on GEOSCAN; however, is inadequate unless publicized through other mechanisms, public awareness of GSC publication released via Geoscan is limited. To enhance publication visibility the mp4 file was posted on YouTube, LinkedIn, and ResearchGate. In this case, LinkedIn proved to be the most successful in reaching an expanded audience. Within one week of posting the animation was viewed by over 800 people, reaching over 3 times the number of LinkedIn connections attributed to the author. LinkedIn provided summary information by country, title (geologist), and company affiliation. Interest in the model was focused in Ontario; however; significant access to the model also occurred in Vancouver and Perth Australia. Based on company affiliation access was logged from a suite of recognized hydrogeological consultants working in Canada, 3D modelling companies in New Zealand, and provincial agencies, e.g. the Alberta Energy Regulator. Penetration within YouTube (32) and ResearchGate (5, 2 days) was one to two orders of magnitude less than via LinkedIn. Additional social media options such as Mendeley, Facebook, and Twitter were not exploited but likely would provide exposure, at least in part, to complementary audiences rather than targeting the same audiences.

GeoScan: **(https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/shorte.web&search1=R=305363)**

Russell, H.A.J., Brodaric, B., Brunton, F.R., Carter, T., Clark, J., Logan, C.E., Sutherland, L., 2017. Communicating 3-D geological models to a wider audience: a case study from southern Ontario. Geological Survey of Canada, Science Presentation. 68. doi:10.4095/305363.

Data Capture, Consolidation and Reclassification: Moving Toward a Geological Framework to Support Groundwater Management in Southern Ontario

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Numerous reports and reviews of groundwater management in Canada, and more specifically in Ontario, have identified the need for the capture and consolidation of data within more structured and accessible database formats with online availability. There remains an enormous amount of valuable legacy geoscience data available in hardcopy and scanned PDF format and more recent work that is primarily available in PDF files. In the past year the GSC has collaborated with the Ontario Geological Survey (OGS), Ministry of Environment and Climate Change (MOECC), Ministry of Natural Resources and Forestry (MNRF), and conservation authorities toward this end. Activities have focused on the data capture, consolidation and classification of data sets collected under the Drinking Water Source Protection Program, legacy municipal and conservation authority information on municipal wells, non-digital legacy data of the OGS and GSC, consolidation of OGS and GSC published work and OGS–GSC geophysical data sets. Work was also completed on enhancing the geological content of the Provincial Groundwater Monitoring Network. Much of this information has been entered into a relational database; however, much of it remains in flat files and requires additional iterative QA/QC before it is suitable for dissemination online.

The most extensive effort was expended on the capture and consolidation of aquifer parameter information tied to municipal wells. Initial efforts focused on Source Protection (SP) reporting available online and expanded to include 19 report types of which 8 were associated with SP and 11 are reports types that may predate SP but support municipal water supplies. To-date approximately 500 reports have been reviewed with 946 municipal wells identified in 32 SP areas, with cross indexing of 84% of the wells with the WWIS and 97% with the PTTW database. Information was assembled on over 30 attributes in 5 general groupings that capture well information. Based on the reports reviewed, 399 aquifer entries, preliminary grouped into 213 aquifers units have been tabulated.

Both the GSC and OGS have legacy hardcopy data holdings that are beig scanned, commonly to a PDF format. This nevertheless leaves the laborious task of capturing pertinent information for consolidation in a database structure. Two distinct activities have been undertaken, i) the capture of legacy section descriptions and analytical data from reports, and ii) consolidation of digital information from standalone publications into a single database. The focus of this activity has been on data that will support the stratigraphic classification necessary for 3-D geological modelling. Addditionally two GSC datasets have been consolidated the downhole geophysical data and reflection seismic data. As part of an ongoing national data compilation new borehole geophysics data collected with the OGS has been integrated into the national dataset. Additionally for the first time reflection seismic data has been consolidated into a database structure bringing together 10 years and hundreds of km of seismic data, of which approximately 20 percent is in southern Ontario.

An ongoing challenge is to complete the necessary QA/QC on the datasets and making them available online. It is anticipated that with the retooling of the Groundwater Information Network (GIN) to the GWML 2.0 standard much of this information will be able to be displayed in the coming 18 months.

Groundwater Resource Management in the Grand River Watershed: Community Engagement and Making the Most of Our Water Budget Tools

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Over the past decade, four Tier 3 water budget studies have been initiated within the Grand River Watershed through the provincial Source Protection Program. Study areas include the Region of Waterloo, City of Guelph and Township of Guelph/Eramosa (Guelph-Guelph/Eramosa Tier 3), Whitemans Creek subwatershed, and most recently the Township of Centre Wellington. The goal of each Tier 3 study has been to evaluate the long term sustainability of the municipalities' aquifers. In each study, numerical groundwater flow models have been developed and applied to assess how water levels in municipal wells will change under various current and future conditions such as changes in land use development, current and future increases in municipal water takings, and long term drought conditions.

In addition to the Tier 3 objectives outlined above, each of the four Tier 3 studies have been leveraged beyond their original purpose to support additional projects, such as the development of municipal Long Term Water Supply Master Plans and climate change adaptation planning.

In the case of the Township of Centre Wellington and Guelph-Guelph/Eramosa Tier 3 studies, a component new to the Tier 3 process has been introduced – early community engagement through the development of community liaison groups. These groups have been implemented to bring engaged residents and stakeholders into the technical portion of the Tier 3 studies as they develop, and into subsequent water quantity policy development.

This presentation provides an overview of how each of the Tier 3 water budget studies within the Grand River Watershed have provided water budget tools, in the form of groundwater flow models, to municipalities for use beyond the Tier 3 assessment, and the evolvement of the Tier 3 process to include community engagement.

A Numerical Study of Barometric Loading

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This work was inspired by a presentation by RVCA at last year's Groundwater Open House, which was a literature review of barometric pressure responses in groundwater level time series data. Barometric pressure changes are known to produce water level fluctuations in monitoring wells while the water level in the aquifer does not change. Last year's review identified barometric loading signals in some PGMN wells, and recommended further research. As it happened, Geofirma had developed modelling tools for other purposes which were well suited to modelling barometric loading phenomena. In particular, we have added a one-dimensional hydromechanical coupling algorithm to TOUGH2, a general-purpose numerical simulation program for multi-phase fluid and heat flow. Unlike many geotechnical and hydrogeological codes, this model explicitly accounts for compressibility of the pore fluid (gas, water, or both). Out of interest, we undertook a small modeling project using this code to simulate barometric loading. This work demonstrates several different possible barometric loading scenarios using an idealized model of a well and aquifer system.

There are two mechanisms responsible for transmission of barometric pressure changes to an aquifer: (1) air flow through the unsaturated zone, and (2) mechanical transmission of pressure changes to subsurface formations. Both mechanisms are present in all hydrogeological settings, but the dominant mechanism is a function of aquifer confinement, compressibility, and the presence or absence of gas. Since observation wells are generally open to the atmosphere, changes in barometric pressure reach the well water almost instantly, but vertical flow due to barometric pressure fluctuations may be delayed in reaching the aquifer or may never reach the aquifer at all. The difference in atmospheric communication between the well water and formation water cause well water levels to fluctuate in order to stay in hydraulic equilibrium with the aquifer.

This project was limited in scope, but the tools and understanding that have been developed could be used to examine a number of questions related to barometric loading, including: the influence of observation well construction on barometric loading, including the effects of wellbore storage, well skin, sealed wells, and buried vibrating wire piezometers; the testing of barometric efficiency, barometric response functions, and other deconvolution algorithms; modelling of the barometric response of specific observation wells, improving understanding of site specific properties and processes governing the barometric response; development of templates or algorithms for assessment of barometric efficiency or barometric response functions; and, the influence of loading by precipitation events or changes in river and lake stage.

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